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# THE DIRECT AND INDIRECT ENERGY REQUIREMENTS OF CANADIAN PRIMARY AND MANUFACTURING INDUSTRIES

by

© NEIL CHARLES MARTIN HUMPHRIES

A THESIS
SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH
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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled The Direct and Indirect Energy Requirements of Canadian Primary and Manufacturing Industries

submitted by Neil Charles Martin Humphries

in partial fulfilment of the requirements for the degree of Master of Arts

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Date Feb 3 1975

# ABSTRACT

The purpose of this thesis is to assess the importance of energy resources as a proportion of the total inputs going into Canadian primary and manufacturing industries. It is shown that measuring energy requirements by the direct inputs of energy products into these industries results in underestimating energy needs. Thus a new approach to the measurement of energy resource requirements was deemed necessary.

The approach chosen was that of Input-Output analysis. Using this technique, a matrix of 'direct plus indirect' requirements of energy resources by Canadian industries was constructed. This matrix was then used to assess the importance of the various energy resource inputs in all of these industries.

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# Chapter I

# INTRODUCTION

## BACKGROUND

In the developed countries of the world energy policy is increasingly being regarded as a very important issue. This is so because the rate of growth of energy consumption in these countries is rising very rapidly, while, at the same time conservationists are urging decreased use of non-renewable energy resources. The concern with energy policy is evidenced by the proliferation of studies on this topic by national governments and international organizations.

In Canada the energy question is of particular importance as this country is both a major producer, and user of many energy resources. It is being increasingly realized here that policy decisions which affect the sale or export of these resources have implications far outside the narrow area of the mineral related industries. In fact, energy policies have effects on almost all areas of the national economy. These effects must be accurately measured if policies in this area are to be rigorously formulated.

## PURPOSE

The purpose of this thesis is to fill some of the data gaps in this area. Thus, it will explore and quantify the usage of energy as an input in Canadian industry and from this progress, to study its importance in Canada's foreign trade in primary and manufactured products.

This paper contends that only through consideration of the direct and indirect energy requirements of industries, in an interindustry context, can a realistic appraisal of the energy economy be made. Approaches which only take into account direct energy use, while ignoring the indirect element, cannot provide an accurate estimate of true energy requirements in an economy.

## FORMAT

The format of this thesis is as follows. Firstly, a chapter will be devoted to an examination of Input-Output techniques in general and then their specific application to the problem of constructing an energy requirements matrix. This table, when derived, will give the 'direct and indirect' energy requirements of one hundred and ten industries in the Canadian economy for eight energy resources. The next chapter will make use of the data in that table to analyze the pattern of energy consumption in Canadian industry. Following will be a chapter containing suggestions on how price changes could be incorportated in the framework used. Finally, a chapter will be devoted to examining the direct and indirect energy requirements of this country's foreign trade.

# Chapter II

# INTRODUCTION TO INPUT-OUTPUT TECHNIQUES

Input-Output analysis is a technique which focuses primarily on the structural interdependence of the producing or consuming sectors in an economy. It is essentially a simplification of the Walrasian general equilibrium system. The pioneering theoretical and empirical work in the field was undertaken by Leontief at Harvard in the 1930's. His original national model for the United States economy has been followed by similar tables constructed by many other countries. Since the first model appeared many new developments have taken place both in the construction and use of this technique.

The starting point of Input-Output analysis is the setting up of an interindustry accounting framework. The basic table involved here is called a "transactions matrix, and it covers all the goods and services produced in an economy. It is distinguished by the fact that productive activities are grouped together in a number of sectors. Each sector appears in the accounting system twice, as a producer of outputs and as a user of inputs. The elements in each row of the table show the disposition made of the output of that sector during the given accounting period."[1]

The interindustry accounting system is of the form outlined in Table 2.1.

Table 2.1

The Interindustry Accounting System

| | Purchases from industry i | Final Use | Supply | |
|---|---|---|---|---|
| | | | Imports | Production |
| | $X_{11} \cdot X_{1j} \cdot X_{1n}$ | $Y_1$ | $M_1$ | $X_1$ |
| | $\vdots \qquad \vdots$ | $\vdots$ | $\vdots$ | |
| Purchases By Industry j | (Quadrant II) | (Quadrant I) | | |
| | $X_{i1} \cdot X_{ij} \cdot X_{in}$ | $Y_i$ | $M_i$ | $X_i$ |
| | $\vdots \qquad \vdots$ | $\vdots$ | $\vdots$ | |
| | $X_{n1} \cdot X_{nj} \cdot X_{nn}$ | $Y_n$ | $M_n$ | $X_n$ |
| | (Quadrant III) | (Quadrant IV) | | |
| Primary Inputs | $V_1 \cdot V_j \cdot V_n$ | $V_y$ | | V |
| Total Production | $X_1 \cdot X_j \cdot X_n$ | Y | M | X |

Source: Table is based on Table 2.2 of Chenery and Clark, Interindustry Economics, p. 16.

In the above diagram quadrant I shows the 'final use' of those commodities produced within the system. In this case it has been shown as total final use of each of those commodities, $Y_i$. Alternatively final use could have been broken down into demand categories such as Government, Investment, etc. The level of aggregation is decided according to the use envisioned for the model. Qudarant II contains the heart of the interindustry accounts. It consists of a matrix of $X_{ij}$'s. Each element of the matrix $[X_{ij}]$ shows the amount of commodity 'i' used by sector 'j' at a given moment in time. These flows are normally measured in current dollar values of the same year. Quadrant III shows the use industries make of primary inputs. These inputs consist of factor returns, i.e. wages to labour, profits, etc. The elements $V_j$ correspond very closely to the definition of value added in each of these industries. Quadrant IV contains the direct inputs of primary factors to final use.

---

[1] H. B. Chenery and Paul G. Clark, Interindustry Economics, (New York: John Wiley and Sons, Inc., 1962), p. 14.

The information shown in the matrix $[X_{ij}]$ is of a purely descriptive nature. It does nonetheless serve a purpose by providing at a glance, a picture of the structural interdependence of the whole economy. By making a series of assumptions however we can transform the simple matrix $[X_{ij}]$ into a model which has valuable analytical uses. These assumptions as listed by Chenery and Clark[2] are:

1. "It must be possible to form the productive sectors in such a way that a single production

---

[2] *Ibid.*, p. 22.

function can be assumed for each one." In addition the Leontief system requires:

2. "that a given product is supplied by one sector only

3. that there are no joint products

4. that the quantity of each input used in production is determined entirely by the level of output of that sector."

"These assumptions of the Input-Out model make it possible to write an equation for the demand $(X_{ij})$ of each industry 'j' for each commodity 'i' as a function of its own level of output $X_j$. These input functions are assumed to be linear over a given range of outputs and hence to be of the following form:

$$X_{ij} = \overline{X}_{ij} + A_{ij}\,X_j\text{"}^{3} \qquad (2.1)$$

The parameter $A_{ij}$ is called the 'marginal input coefficient.' The constant $\overline{X}_{ij}$ includes any fixed constant element which does not vary with the level of output. When it is zero, the input function becomes:

$$X_{ij} = A_{ij}\,X_j \qquad (2.2)$$

or

$$A_{ij} = \frac{X_{ij}}{X_j}$$

From the interindustry flow matrix $[X_{ij}]$ and the vector of final outputs $[X_j]$ we construct a matrix $[A_{ij}]$. Its elements $A_{ij}$'s are fixed and show the

---

[3] *Ibid.*, p. 23.

amount of commodity 'i' required by industry 'j' per unit of its output. In the Leontief system this matrix is square and it is called the 'technology matrix.' For a 'n' sector model it would look like:

$$A = \begin{bmatrix} A_{11} & \cdots & A_{1n} \\ \vdots & & \vdots \\ A_{n1} & \cdots & A_{nn} \end{bmatrix}$$

Total production levels and final demand are written respectively as the column vectors X and Y.

$$X = \begin{bmatrix} X_1 \\ \vdots \\ X_n \end{bmatrix} \qquad Y = \begin{bmatrix} Y_1 \\ \vdots \\ Y_n \end{bmatrix}$$

The product of the technology matrix and the vector of production levels form a new column vector which is the vector of "intermediate demands" W.

$$\text{i.e.} \quad AX = W \qquad (2.4)$$

Using a simplified form of the "balance equation for each commodity or sector" given by Chenery and Clark[4]

$$X_i - \sum_j A_{ij} X_j = Y_i \quad (i,j = 1,2 \ldots n) \qquad (2.5)$$

or in matrix form:

$$X - AX = Y \qquad (2.6)$$

$$\text{or} \quad [I - A]X = Y \qquad (2.7)$$

This system can be solved as follows:

---

[4] Ibid.

$$X = [I - A]^{-1}Y$$

This solution for a two industry case would look like

$$\begin{bmatrix} X_1 \\ X_2 \end{bmatrix} = \begin{bmatrix} r_{11} & r_{12} \\ r_{21} & r_{22} \end{bmatrix} \begin{bmatrix} Y_1 \\ Y_2 \end{bmatrix} \qquad (2.9)$$

where the $r_{ij}$'s are elements of the inverse matrix. Each $r_{ij}$ shows the amount of commodity i that must be produced to satisfy a final demand of 1.0 in sector 'j.'

This matrix $[I - A]^{-1}$ is our interdependence matrix or our table of 'direct plus indirect' effects. The matrix solution although it is the most efficient tends to blur the economic interactions which lie behind the system.

Miernyk[5] describes the matrix as a table which "shows the total expansion of output in all industries as a result of the delivery of one dollar's worth of output outside the processing sector by each industry."[6] He goes on to show how this table could be alternatively derived using a process of iteration. This procedure throws a lot of light on the economic interpretation of the matrix of 'direct plus indirect' effects. The following hypothetical input-coefficient table will be used to illustrate the method.

---

[5] W. H. Miernyk, The Elements of Input-Output Analysis, (Random House, 1965).

[6] Ibid., p. 24.

Table 2.2

Hypothetical Transactions Table

| | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| A | 3¢ | 7¢ | 16¢ | 13¢ | 8¢ | 17¢ |
| B | 11¢ | 26¢ | 7¢ | 8¢ | 7¢ | 2¢ |
| C | 18¢ | 4¢ | 21¢ | 3¢ | 18¢ | 5¢ |
| D | 15¢ | 2¢ | 21¢ | 5¢ | 3¢ | 21¢ |
| E | 5¢ | 0 | 8¢ | 0 | 8¢ | 16¢ |
| F | 13¢ | 11¢ | 13¢ | 3¢ | 18¢ | 9¢ |

Using the above table the total effect of a one dollar increase in final demand for the output of one industry will be traced through the system. Assume for example that the increase in final demand is for the products of industry B. This one dollar increase in final demand will increase intraindustry transactions by 26¢. Thus the gross output of industry B will increase by at least $1.26. But when the output of industry B increases, the firms in this industry will step up their purchases from industry C. Sales from industry C to industry B will go up an additional 5¢ ($1.26 x .04) as a result of the increased activity in industry B. Similarly, sales from industry D to B will increase by 2.3¢ and so on down column 2 of table 2.2.

The indirect effects do not stop here. When industry C expands its production because of an increase in final demand for commodity B, the increased demand thus generated will be felt by C's suppliers. So on for the other industries which supply B. The calculations above could be repeated to include each industry in the processing sector. Then, by adding up all the figures a table would gradually be built up which would show the total requirements, direct and indirect, resulting from the delivery of one dollar's worth of the products of each industry in the processing sector to the final use sector. Such a table is of course equivalent to inverting the [I - A] matrix.

## THE 1961 CANADIAN MODEL[7]

The latest Canadian Input-Output table has some features which do not correspond to the general models outlined above. For example, both the inputs and outputs of industries are classified in two ways, (a) according to the producing or using industry and (b) according to the commodity produced or used. Furthermore, in the new system the number of commodities is greater than the number of industries. Hence the one to one correspondence between industries and their principal product does not exist. Instead the characteristic product of each industry is often subdivided into several commodities. As a result the tables showing the outputs and intermediate inputs of industries are rectangular rather than square.

---

[7] Canada, Dominion Bureau of Statistics, The Input-Output Structure of the Canadian Economy, 1961, (Ottawa: Queen's Printer, 1969).

Models of this particular structure involve two sets of assumptions. "The first has the function of allocating the production of commodities among industries. The second establishes the production functions of industries, which in turn determine the requirements of industries for commodity inputs. These assumptions, in conjunction with the accounting balance between total demand less imports of competing products and domestic production, establish input-output models in which outputs are determined as a function of final demand less imports."[8]

The notation used is a follows:

e is a vector of final demand less imports of competing commodities

q is a vector of commodity outputs

g is a vector of industry outputs

B is the 'technology matrix'

D is the market share matrix. It is based on the assumption that industries will preserve their share of the market for each commodity, regardless of the levels of commodity production.

The solutions to the model are:

---

[8] *Ibid.*, Vol. I, p. 137.

$$q = [I - BD]^{-1} e \qquad (2.10)$$

and $$g = [I - DB]^{-1} De \qquad (2.11)$$

These two expressions define linear transformations of final demand less imports, into commodity output in the case of equation (2.10), and into industry outputs in the case of equation (2.11).

In the model so far 'competing imports' are treated as exogenous and 'non-competing imports' as being determined endogenous. That is, the latter are determined by the levels of industry outputs when they are used by industries, or are prespecified as part of final demand when they are used for final purposes. However in some of the impact tables published, all imports are treated as endogenous A brief description of these tables, which are called 'impact tables with import leakages,' will now be presented.

The way in which imports are made endogenous is in fact quite simple. It is assumed that such imports form a stable proportion of the total supply of each commodity. This is expressed as

$$M = U (q + M) \qquad (2.12)$$

where the vector M represents competing imports, U is a diagonal matrix of coefficients whose elements are computed as the ratio of competing imports to total supply for each commodity, q is the vector of total commodity outputs. The vector sum (q + M) represents therefore the values of total supply of commodities.

A new market share matrix and a vector of final demand are now defined and used to replace D and e in the solution given by equation (2.11). The solution then becomes:

$$g = [I - D^*B]^{-1} D^*e^* \qquad (2.13)$$

where $$D^* = D[I - U] \qquad (2.14)$$

and $$e^* = e + M \qquad (2.15)$$

In equation (2.13) $D^*$ or $D[I-U]$ is the new market-share matrix for which the market-share coefficients of industries are calculated as a proportion of the total supply of each commodity, rather than as a proportion of the domestic production of that commodity.

In the sections that follow only the impact table without import leakages will be used. The operations described in the following section were, however, applied to both impact tables. Thus while data was available, calculated on the basis of the impact table with import leakages it was decided not to include it in this paper.

## METHOD OF THE STUDY

### The Energy Input-Output Table and Its Limitations

An energy Input-Output table is a matrix which consists of coefficients which show the direct and indirect requirements of specified energy resources by a set of industries. Such a table is not a self-contained unit in the sense that it could be constructed in isolation. It must, in fact, be derived in some way from an input-output model for the whole economy in question. The complete model is necessary as it is precisely the flows of commodities, embodying energy, between the total of all industries in an economy that gives us the complete picture of energy requirements. These transactions only appear when the whole interindustry matrix is inverted.

The quality of any energy table produced is thus obviously dependent on the standard of the overall models existing for the economy in question. One of the most desirable qualities in any input-output model is up-to-date coefficients. This depends, of course, on how often the interindustry data is reviewed. The ideal situation would be one in which the coefficients were revised on the basis of annually collected industry data. Such a procedure is unlikely to be followed anywhere due both to the cost and time involved in adjusting such coefficients. This latter constraint is, however, becoming less strict as data processing becomes more computerized.

Another desirable quality of an input-output model in relation to energy would be some method of differentiating between the use of an energy resource as feedstock and as a source of power. This separation is important since that quantity of the resource used as feedstock is less easily replaced by another 'energy resource,' than that used for power. Some of the difficulties here could, of course, be removed by using more disaggregated input-output models. For example, 'coal' could be divided into various subcategories, some of which are obviously feedstock and some sources of energy. In other cases, however, the solution is not so simple. Natural gas, for example, could be used by a chemical plant both as a feedstock and as a source of heat. No indication of which use would be given by the flow of natural gas from the 'gas' industry to the chemical industry.

The data available for this study had some specific limitations. Instead of regularly revised coefficients, the data was based on observations for only one year, 1961. Using this information means that coefficients which describe the industrial structure of 1961 are being used to approximate the current economic structure. This may be a fairly weak approximation given the great deal of technological advance made during the last eleven years.

The energy field is one area in which there has been considerable technological change. This has resulted in substitution among some energy sources. The extent of this substitution, which is virtually ignored in this paper, is illustrated in the following table which shows the changing pattern of energy consumption in Canadian Manufacturing industry.

Table 2.3

Relative Importance of Various Energy Sources in Canadian Manufacturing Industry

| | 1965 | 1967 | 1969 |
|---|---|---|---|
| Gasoline | 7.05 | 6.85 | 6.70 |
| Fuel Oil | 20.03 | 20.85 | 19.00 |
| Liquid Petroleum Gas | .74 | .84 | 1.00 |
| Natural Gas | 9.84 | 12.39 | 14.68 |
| Electricity | 43.33 | 43.90 | 46.28 |
| Other | 19.11 | 15.17 | 12.34 |
| Total | 100.00 | 100.00 | 100.00 |

Source: Calculated from Dominion Bureau of Statistics, "Energy Statistics-Service Bulletin." Various Issues.

The changes in relative importance of different energy resources, which can be seen in the above table, were caused partly by price differentials changing over time and partly by a technological trend in favour of cleaner and more efficient fuels.

## Sources and Method for the Construction of the Energy Input-Output Table

The 'direct plus indirect' energy coefficients required by this paper were not to be found in any of the Input-Output tables published by the Dominion

Bureau of Statistics.[9] It was, however, possible to derive them using data contained in these tables.

One method by which they could be calculated would be to premultiply the 110 x 197 impact table[10] by the eight selected energy rows from the 197 x 110 input-coefficient table.[11] This would not, however, directly give the coefficients required by this paper, namely coefficients showing the 'direct plus indirect' energy required by the 110 industries. Rather, it would give coefficients which show the energy content of 197 commodities produced by these industries. However, having derived this 8 x 197 commodity matrix, it would be theoretically possible to consolidate it into a 8 x 110 industry matrix by using market share coefficients similar to those provided for aggregation S.[12] Statistics Canada will not, however, provide such a table at this level of aggregation as they claim it would constitute a breach of confidentiality. This is so because in some industries there are only a very few firms and detailed information on these industries would, in fact, involve supplying information on specific firms.

---

[9] Ibid., Vol. II.

[10] Ibid., Vol. II, Table 15.

[11] Ibid., Table 14.

[12] Ibid., Vol. I, Table 4.

Another method, and this is the one actually used in this study, relies on unpublished information. This became possible when it was found that a 110 x 110 flow table was obtainable on data tape from Statistics Canada. This table is simply an alternative aggregation of the data published in the 1969 study. From this table an input-coefficient table was constructed and then the corresponding impact or $[I - A]^{-1}$ was calculated. By premultiplying this by the 8 x 110 energy input matrix the required industry table was obtained.

In actuality, two input-output tables were obtained from Statistics Canada. In one of these competing imports were treated as exogenous whereas in the other they were endogenous. These two matrices resulted in impact tables respectively without and with import leakages. Since the operations involved in constructing an energy impact table either with or without import leakages are the same, in the following they will be treated as one. Except where specifically noted the table used in the following is that in which competing imports are treated as exogenous.

What follows is an attempt to outline in more detail the procedures described in the previous two paragraphs. It must be remembered that the notation used in the following is a simplified version of that involved in the Canadian table.

The matrix $[I - A]^{-1}$ 110 x 110 is an impact table or a table of interdependency coefficients. Each element of this matrix, which will be denoted by $(r_{ij})$ shows the amount of commodity i required directly and indirectly to satisfy a final demand of 1 unit in sector j.

The matrix E 8 x 110 is a table of direct energy coefficients. It consists of eight rows extracted from table 14 of the "Input-Output Structure of the Canadian Economy." Each element of this $(E_{kj})$ shows the amount of a specific energy resource required directly by sector j per unit of output.

Now when the $[I - A]^{-1}$ 110 x 110 matrix is premultiplied by the E 8 x 110 matrix the result is the product matrix P 8 x 110. Each element of this $(P_{kj})$ shows the amount of the particular energy resource 'k' required directly and indirectly to meet a final demand of one unit in industry 'j.'

A simplified example will illustrate what occurs in these matrix operations. Using just two energy resources, coal (c) and natural gas (n), and a four commodity by four industry impact table, a sample result will be derived. In matrix terms the operation is expressed as follows:

$$E \cdot R = P \qquad (2.16)$$

However, in the more expanded form this appears as:

$$\begin{bmatrix} E_{c1} & E_{c2} & E_{c3} & E_{c4} \\ E_{n1} & E_{n2} & E_{n3} & E_{n4} \end{bmatrix} \begin{bmatrix} r_{11} & r_{12} & r_{13} & r_{14} \\ r_{21} & r_{22} & r_{23} & r_{24} \\ r_{31} & r_{32} & r_{33} & r_{34} \\ r_{41} & r_{42} & r_{43} & r_{44} \end{bmatrix}$$

$$= \begin{bmatrix} p_{c1} & p_{c2} & p_{c3} & p_{c4} \\ p_{n1} & p_{n2} & p_{n3} & p_{n4} \end{bmatrix}$$

Taking as an example one element from the p matrix and expanding it

$$p_{c1} = E_{c1}\, r_{11} + E_{c2}\, r_{21} + E_{c3}\, r_{31} + E_{c4}\, r_{41}$$

Now in this expression:

$E_{ci}$ shows the amount of coal required to produce one unit of output of sector i, $i = 1 \cdots 4$

$r_{i1}$ is the amount of the output of each industry i, $i = 1 \cdots 4$ required directly and indirectly to meet a final demand of one unit in sector 1.

The product of these two expressions $E_{ci}\, r_{i1}$, which is equivalent to $p_{c1}$, then obviously shows the amount of coal required directly and indirectly to meet a final demand of one unit in sector 1.

In the more general case the sum $\sum_{i=1}^{110} E_{ci}\, r_{ij}$ is calculated for each j, $j = 1 \cdots 110$. This produces a set of 'direct plus indirect' coal requirement coefficients for the 110 industries. When similar coefficients are calculated for the other energy resources an 8 x 110 energy impact table is eventually arrived at. The above operations are not done separately but are completed automatically in the matrix operation E.R.

Having explained in this chapter how the energy requirements matrix was produced and what its limitations are, the following chapters will make use of the data generated to analyze the various aspects of energy use in the Canadian economy.

The technique outlined above is similar to that used in estimating the direct plus indirect requirements of primary inputs such as labour or water.[13] However, the resources under study in this paper have industries, in the 110 x 110 inverse, associated with their production. This means that they are not entirely primary inputs to the system. As a result errors exist in the case of some of the estimated energy requirement coefficients. The estimates concerned are those for the energy producing industries themselves. The 'direct plus indirect' requirements of these industries, for those energy resources which they produce themselves, are consistently underestimated. The coefficients which in fact emerge in these cases show only the indirect requirements. That is, they do not include the amount, equal to unity, which is required by these industries directly to meet a unit increase in final demand for their own output.

For example the estimated amount of coal required, directly and indirectly, by the coal industry to meet a final demand of $1 is shown as $.087085 whereas in fact it should be $1.087085.

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[13] P. Zusman and I. Hoch, Resource and Capital Requirements for the California Economy. (California: Giannini Foundation of Agricultural Economics 1965).

For the estimation procedure to be valid in all cases the four energy industries would have to be extracted from the 110 x 110 inverse matrix. This method was not followed as it would have involved much more resources and time than were available for this paper. None of this however affects the validity of the 'direct plus indirect' coefficients estimated for the 106 non-energy industries. These still remain good estimates.

# Chapter III

# ENERGY IN THE NATIONAL ECONOMY

## INTRODUCTION

In this chapter a detailed analysis will be made of the pattern of energy use in the Canadian economy. This will be accomplished using the data generated by the methods outlined in Chapter II, together with information directly available from the 1961 Canadian Input-Output table.[1] The focus of this study will be on energy as a input into the productive process, rather than as an end-product commodity. Consideration will be given both to the aggregate energy input and to the individual energy resources which make up this total. This study will go further than a previous one[2] in that the indirect energy consumed by industries will also be included in the measure of energy intensity. By using this approach a more complete picture of energy in the economy will be presented.

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[1] Ibid., Vol. II, Tables 13 and 14.

[2] Douglas H. Younie, Factors Affecting the Location of Energy Intensive Industries. (M.A. Thesis, unpublished; University of Alberta, Faculty of Graduate Studies and Research, 1972).

The plan of the chapter will be as follows. Firstly, a definition of energy content will be given, and then the eight energy resources included in this definition will be described. Following this a study of the aggregate energy contents of the 110 'industries' will be presented and the implications of including indirect energy use in this measure explored. Then the pattern of use, both direct and indirect, of the individual energy resources will be examined in detail. It will be shown that, in many cases, large indirect consumption of energy by particular industries can be explained in terms of strong backward links[3] from these to a few industries which are particularly heavy direct users of energy.

## ENERGY INTENSITY AND THE ENERGY RESOURCES DEFINED

For the purpose of this study 'energy content' is measured as the dollar value of the eight energy resources going into any industry per unit of that industry's output. There are two definitions of energy content used in this chapter. The first, 'Direct Energy Content' (DE) consists of the value of these resources going into any industry as a direct material input. The second, 'direct plus indirect energy content' (DIE) includes in addition to this the amount of these resources going into the industry indirectly through being embodied in purchased, processed or fabricated material and non-material inputs.

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[3] For a definition of backward linkages see: A. O. Hirschmann, The Strategy of Economic Development, (New Haven: Yale University Press, 1965), p. 201.

The use of dollar values instead of some physical measure such as British Thermal Units (B.T.U.) has its advantages and disadvantages. The principal advantage is that by using dollar values energy is put on a basis comparable with any other input, such as labour or capital. The main disadvantage is that the important elements of fuel efficiency and price differences are being ignored. For example, $1 each worth of petroleum, natural gas and electric power might not provide the same amount of B.T.U.'s as, say, $3's worth of electric power. However, in this study the only recorded fact is that $3's worth of fuel was consumed.

In any discussion of energy a problem arises over what constitutes an energy resource. Ideally it is claimed, only fuels should be included in this set. However, given limitations of data it is not always possible to isolate fuels from feedstock. This is so because a given energy resource might provide the two functions at the same time. A good example of this in the present situation is Natural Gas. This resource may provide feedstock and heating to a chemical plant with no indication in the data of what proportion of the gas consumed is used for which function.

In choosing the energy resources for this study, all resources were included which possessed any fuel properties. Although this meant including resources whose prime use was as feedstock, this strategy was deemed acceptable in order that no fuel whatever in use would be excluded. Another consideration which led to the inclusion of these resources is that they are often produced as joint products with fuels, and hence any changes in the demand for them could result in altered production and prices for these fuels.

As a result of this reasoning, eight resources were selected from the D.B.S. 197 Input-Output commodity classification and these were defined as the energy resources. These eight resources are listed in Table 3.1 and there follows a description of the energy resources, and then their energy characteristics will be examined.

Coal. This is a fossil fuel and is used industrially both as a fuel and as a raw material. It is impossible to separate its two functions at the level of aggregation used in this study.

Natural Gas. This resource also serves two functions in production. It is used as fuel both directly and through conversion to electricity. Some

Table 3.1

The Energy Resources

| D.B.S. # | Name |
|---|---|
| 16 | Coal |
| 17 | Crude Mineral Oil |
| 18 | Natural Gas |
| 152 | Gasoline |
| 153 | Fuel Oil |
| 154 | Lube Oil and Grease |
| 155 | Other Petroleum Products |
| 184 | Electric Power |

Source: selected from list of 197 commodities in, Bureau of Statistics, The Input-Output Structure of the Canadian Economy, 1961, Vol. I, pp. 251-261.

chemical industries use it as a feedstock.

Crude Mineral Oil. This is the least processed of the petroleum products. The main consumer of this resource is the petroleum products industry where it serves as feedstock but also has some fuel uses.

Gasoline. This serves almost solely as a fuel providing motive power through internal combustion engines.

Fuel Oil. As its name indicates, its use is primarily as a fuel. It includes diesel oil and oils used for heating purposes.

Lube Oil and Grease. This is a petroleum product used by industry for lubrication purposes.

Other Petroleum Products. This includes such various commodities as petroleum wax and liquified petroleum gases. These latter are used for power and feedstock.

Electricity. This is a produced energy source and is produced either by hydro or thermal generation. It is the most flexible of all the energy sources and that probably accounts for its widespread industrial use. It provides both motive and thermal power and is used as a feedstock in some electro-process industries.

## DIRECT AND INDIRECT TOTAL ENERGY USE BY SECTORS AND INDUSTRIES

In this section the total energy content of the 110 industries is discussed. The data on which this discussion is based is set out in detail in Table A.1 in the Appendix. From this table the industries which are energy intensive with respect to 'direct plus indirect' use are selected. Rather than choosing some arbitrary cut-off point in order to define the energy intensive industries, such as, say 10¢ worth of energy per dollar of output, it was decided instead to concentrate on the top twenty most energy intensive industries. This has been done in order to facilitate a comparison between two sets of industries. The first set consists of the twenty industries with the greatest direct energy content among the 110. The other is composed of those with the highest direct plus indirect energy content. These two sets of industries are set out respectively in Tables 3.2 and 3.3. The key to these two tables is, P = Primary, P.M = Primary Manufacturing, and S.M = Secondary Manufacturing.

## Sector Differences Examined

On comparing these two tables, a few interesting points emerge immediately. Firstly, the average energy intensity of the twenty industries is far greater for the second group. Also there are noticeable differences in the industries included and the sectors represented in the two groups.

First of all, the average energy intensity of the industries in Table 3.3 is 14.9¢ while that of those in Table 3.2 is 9.5¢. This difference is, however, much greater if we exclude the top two industries which are extremely heavy direct users of energy for feedstock. The figures then become respectively 11.5¢ and 5.5¢. The industries in Table 3.3 are thus on average more than twice as energy intensive as those in Table 3.2.

Also it is noticeable that the primary sector has lost its importance when the top twenty industries

## Table 3.2

### Top Twenty Direct Energy Users

| Industry | Sector | Direct Energy Input per $ of Output of the Industry |
|---|---|---|
| Petroleum Products Ind. | P.M | 60.0¢ |
| Utilities | T | 20.2¢ |
| Cement and Lime Mfg. | P.M | 11.3 |
| Oth. Chemical Ind. | S.M | 10.4 |
| Iron and Steel Mills | P.M | 9.0 |
| Asphalt Roofing | S.M | 7.9 |
| Ao-Non-Metal Mines | P | 6.9 |
| Oth. Non-Metal Min. | P | 6.1 |
| Pulp and Paper Mills | P.M | 6.0 |
| Agriculture | P | 5.8 |
| Clay Stone and Refrac. | P.M | 5.7 |
| Coal Mines | P | 5.7 |
| Oth. Metal Mines | P | 5.6 |
| Fishing and Hunting | P | 4.7 |
| Plastic Resin Mfg. | S.M | 4.6 |
| Transport and Storage | T | 4.4 |
| Oth. Wood Ind. | S.M | 4.3 |
| Asbestos Mines | P | 4.3 |
| Iron Mines | P | 4.0 |
| Wholesale and Retail | T | 3.1 |
| Average | 9.5¢ | |

Source: Calculated from Dominion Bureau of Statistics, The Input-Output Structure of the Canadian Economy, 1961, Vol. II, Table 13.

## Table 3.3

### Top Twenty Direct Plus Indirect Energy Users

| Industry | Sector | Direct + Indirect Energy Required per $ of Final Demand |
|---|---|---|
| Petroleum Products Ind. | P.M | 65.5¢ |
| Utilities | T | 25.9¢ |
| Other Chemical Inds. | S.M | 19.4 |
| Asphalt Roofing | S.M | 16.9 |
| Cement and Lime Mfg. | P.M | 16.2 |
| Iron and Steel Mills | P.M | 14.7 |
| Plastic Resin Mfg. | S.M | 13.8 |
| AO. Non-Metal Mines | P | 12.5 |
| Agriculture | P | 12.4 |
| Oth. Non-Metal Min. | P | 12.1 |
| Paint and Varnish | S.M | 11.7 |
| Veg. Oil Mills | S.M | 11.6 |
| Pulp and Paper Mills | P.M | 11.5 |
| Clay, Stone and Refrac. | P.M | 11.3 |
| Leaf Tobacco Proc. | P.M | 11.0 |
| Dairy Factories | P.M | 10.9 |
| Steel Pipe and Tube | S.M | 10.4 |
| Flour Mills | P.M | 10.2 |
| Other Wood Ind. | P.M | 10.0 |
| Meat Processing | P.M | 9.7 |

Average 14.9¢

Source: Table A.1 in Appendix.

are respecified to include those with the highest 'direct plus indirect' energy content. The number of secondary and primary manufacturing industries in the group has increased. This has happened due to the inclusion of indirect energy content which is a function of (a) the proportion of total inputs of an industry coming from other industries in the system, and (b) the energy content of these intermediate input industries. In the case of the primary industries, backward linkages are generally weaker than in the secondary and primary manufacturing industries. Thus, unless these industries are linked to some few very energy intensive input industries, indirect energy consumption would be below average, causing the primary industries to be omitted from the top ranking when direct plus indirect energy content is used as the measure of energy intensity.

## Industry Differentials Examined

An interesting subset of the industries in Table 3.3 is the set of those which did not rank in the top twenty when only direct energy content was considered. These are the industries which now have significant energy contents due to the inclusion of the indirect element. These industries are set out in Table 3.4, along with some information which should throw some light on their position. In this table the 'Largest Link Industry' and 'Measure of Largest

## Table 3.4

### Industries From Table 3.3 with Large Indirect Energy Contents

| Industry | Direct Energy Content | Direct & Indirect Energy Content | Largest Link Industry | Measure of Largest Link | Direct Energy Content of Link Ind. |
|---|---|---|---|---|---|
| Paint and Varnish | 3.0¢ | 11.7¢ | Ind. and Oth. Chemicals | .276 | 10.4¢ |
| Veg. Oil Mills | 0.9¢ | 11.6¢ | Agriculture | .895 | 5.8¢ |
| Leaf Tobacco Proc. | 0.3¢ | 11.0¢ | Agriculture | .918 | 5.8¢ |
| Dairy Factories | 1.5¢ | 10.9¢ | Agriculture | .683 | 5.8¢ |
| Steel Pipe and Tube | 1.1¢ | 10.4¢ | Iron and Steel Mills | .597 | 9.0¢ |
| Flour Mills | 0.7¢ | 10.2¢ | Agriculture | .727 | 5.8¢ |
| Meat Processing | 0.5¢ | 9.7¢ | Agriculture | .721 | 5.8¢ |

Sources: Calculated from: Dominion Bureau of Statistics, The Input-Output Structure of the Canadian Economy, 1961, Vol. II, Table 13.

Table A.1 in Appendix.

Link' were derived from $[I - A]^{-1}$ 110 x 110 matrix. They were found by obtaining the largest coefficient in the column of the industry in question. Those coefficients, which are called here the 'Measures of the Largest Link,' show the dollar value of the input from the industry named required to meet a final demand of one dollar for the industry in question. The largest coefficient in any row indicates the most important input industry, which is called here the 'Largest Link Industry.'

All of the industries in Table 3.4 are in the bottom half of the top twenty 'direct plus indirect' energy intensive, industry list. They still, however, have significant energy contents. What the table attempts to show is that these industries are all heavily linked to one of the directly energy intensive industries. This means that a large part of their indirect energy consumption is directly traceable to one particular intermediate source. Being able thus to account for the major portion of the indirect energy consumed by an industry could be very important in a detailed study of the effects of energy price changes. For example, if it is known that a given industry consumes a major portion of its energy indirectly through purchases of inputs from the agricultural rather than the machinery industry, and if, in addition, the differential abilities of these two industries to pass on cost increases is known, then the effects of an energy price increase on the industry in question could be more accurately estimated because of the knowledge that it is from the agricultural industry that it gets its large indirect input of energy.

## EXAMINATION OF THE 'DIRECT AND INDIRECT' REQUIREMENTS FOR THE INDIVIDUAL ENERGY RESOURCES

### An Overview

The data on which this section draws is set out in full in Table A.2 of the Appendix. This table lists the 110 industries, giving for each the dollar value of each of the energy resources required to meet a final demand of one dollar for the output of the industry in question. To make the data more workable, in this chapter these figures have been expressed in cents to one decimal place. All the averages which appear here are based on this corrected data.

The first fact explored in this chapter is the relative importance of the various energy resources for the total of the 110 industries. Thus in Table 3.5 the average 'direct plus indirect' content of each resource over the 110 industries is set out. From this overall view of the economy, two resources emerge as being particularly important: Crude Mineral Oil, and Electric Power. However, these broad national averages often provide a misleading picture of the relative importance of the different energy resources in the economy. This is so because, in addition to the overall quantity consumed of a given energy resource, its dispersion in use among the various sectors and industries is also a very important factor to consider. An example of this is Crude Mineral Oil where the national average consumption 'direct and indirect' is very large. However, this large national average hides the fact that this resource is of great importance to only one industry, the petroleum products industry, and is only of minor importance to the other 109. It can clearly be seen from this, that in order to fully understand the nature of energy consumption in the economy, the relative importance of the various energy types at the sector and industry level must be examined.

Table 3.5

Average Direct and Indirect Content of Each Resource Over 110 Industries

| Resource | Average Direct & Indirect Content per $ of Final Demand |
|---|---|
| Coal | 0.7¢ |
| Crude Mineral Oil | 2.0¢ |
| Natural Gas | 0.1¢ |
| Gasoline | 0.7¢ |
| Fuel Oil | 1.0¢ |
| Lube Oil and Grease | 0.2¢ |
| Other Petroleum Products | 0.6¢ |
| Electrical Power | 2.5¢ |

Source: Calculated from data in Appendix, Table A.2.

## Sector and Industry Level. Analysis

The approach chosen here is to look at the individual energy resources consumed at the sectoral level and whenever striking intersectoral differences emerge in average amounts consumed of a given energy resource, to refer back to the industry level and attempt to explain them. By following this procedure an overview is achieved, without ignoring significant industry detail. In accordance with this plan, sector averages were computed for each of the eight energy resources. This data is set out in Table 3.6. Starting with this table, the individual resources will now be examined individually.

### Coal

By far the greatest consumption, directly and indirectly, of coal comes from the secondary and primary manufacturing sectors; substantially more coal being used by the latter. Two industries, between them, account for a large part of the primary manufacturing sector's consumption. These are Iron and Steel Mills (6.4¢) and Cement and Lime Mfg. (5.0¢). Both these industries are also heavy direct users of coal inputs. In the secondary manufacturing sector it is much more difficult to associate the large consumption of coal to any particular heavy user industries. This is because most of the coal used in

## Table 3.6

### Amount in Cents of Each Energy Source Required to Meet a Final Demand of One Dollar For Each Industry: Averaged by Sector

| Resource<br>Sector | Coal | Crude Mineral Oil | Natural Gas* | Gasoline | Fuel Oil | Lube Oil and Grease | Other Petroleum Products | Electric Power |
|---|---|---|---|---|---|---|---|---|
| Primary | 0.3 | 1.8 | - | 1.3 | 1.1 | 0.4 | 0.2 | 2.9 |
| Primary Manufacturing | 1.3 | 5.6 | - | 1.6 | 1.4 | 0.4 | 0.4 | 3.1 |
| Secondary Manufacturing | 0.8 | 1.3 | - | 0.5 | 0.9 | 0.2 | 0.8 | 2.3 |
| Tertiary | 0.2 | 1.2 | - | 0.5 | 1.0 | 0.1 | 0.3 | 2.9 |

Source: Calculated from data in Appendix, Table A.2.

*Averages for Natural Gas were not calculated.

this sector is indirectly consumed through intermediate inputs which are common to most industries there. The heaviest users of coal, directly and indirectly, are, however, Steel Pipe and Tube (3.6¢) and Fabr. Structural Metal (2.5¢). Examination of these industries shows that they are not heavy direct users of coal--the figures for direct coal inputs being .01¢ and .04¢ respectively. It can be shown that these two industries get much of their indirect coal content embodied in their large intermediate purchases from the Iron and Steel Mills. Steel Pipe and Tube requires 59.7¢ of input from Iron and Steel Mills to meet a final demand of one dollar for itself. Fabr. Structural Metal required 39.6¢ worth. It is also likely that all the other secondary manufacturing industries get their indirect coal content from the two large direct users, the Iron and Steel Mills and the Cement and Lime Mfg. Ind. since these two industries provide inputs to almost all industry.

## Crude Mineral Oil

The Primary Manufacturing sector is by far the largest 'direct plus indirect' user of this energy product. This is because the Petroleum Products Industry is situated there, and it requires 59.7¢ worth per dollar of final demand. This is also the only industry which has any significant direct input of crude mineral oil. The consumption of crude, directly and indirectly, is pretty evenly spread among the other 109 industries and this use is almost completely indirect. These industries get their indirect crude content through their purchase of intermediate inputs from the Petroleum Products industry which has extremely heavy forward linkages. Purchases by other industries from the Petroleum Products Industry vary only from 1 to 7¢ per dollar of final demand.

### Natural Gas

No averages were computed here as the figures would turn out too small to be meaningful. In fact, the individual industry coefficients are, in general, insignificant. This is because the Natural Gas economy had barely emerged in Canada in 1961.[4]

### Gasoline

The principal use of this resource is in the primary, and primary manufacturing sectors. There are a few key industries in these sectors which help account for the higher sector averages. These industries are listed in Table 3.7 with their 'direct plus indirect' (DI) and 'direct' (D) gasoline contents being shown for comparison.

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[4] To indicate how insignificant natural gas utilization was in 1961 in the Canadian Economy, the three most natural gas intensive industries will be listed along with their direct plus indirect natural gas content: Cement and Lime Mfg. (0.6¢), Clay, Stone and Refrac. (0.4¢) and Glass and Products Mfg. (0.2¢).

Table 3.7

The Gasoline Intensive Industries

| | DI | D |
|---|---|---|
| **Primary** | | |
| Agriculture | 4.2¢ | 3.6¢ |
| Forestry | 1.9¢ | 1.4¢ |
| Hunting and Fishing | 3.9¢ | 3.7¢ |
| AO Non-Metal Mines | 2.0¢ | 1.7¢ |
| **Primary Manufacturing** | | |
| Meat Processing | 2.9¢ | 0.04¢ |
| Pulp and Paper Mills | 2.9¢ | 0.1¢ |
| Dairy Factories | 3.2¢ | 0.5¢ |
| Fish Products Ind. | 2.3¢ | 0.1¢ |
| Flour Mills | 2.9¢ | 0.02¢ |
| Leaf Tobacco Proc. | 3.5¢ | 0.01¢ |

Source: Calculated from Dominion Bureau of Statistics, The Input-Output Structure of the Canadian Economy, 1961, Vol. II, Table 13

Table A.2 in the Appendix of this paper.

By comparing the 'direct' with the 'direct plus indirect' gasoline content, much can be learned about the industries in Table 3.7. For the first group, the primary industries, there is little difference between the two quantities. This indicates that the gasoline content of these industries comes principally from direct inputs of gasoline. Quite the opposite is true of the secondary manufacturing group. Their gasoline consumption is predominantly indirect. An examination of the industries involved would point to the conclusion that much of this indirect gasoline consumption takes place through the use of inputs from the first three industries in the primary group in Table 3.7. This is confirmed by looking at the $[I - A]^{-1}$ 110 x 110 matrix where strong links are seen to exist from these gasoline intensive primary industries to their processing industries in the primary manufacturing sector.

### Fuel Oil

There is little difference among the sectors with respect to their average 'direct plus indirect' use of fuel oil. Also, for the individual industries within any sector there is very little deviation from the sector average. Another factor peculiar to this resource is that there is very little difference between the figures for direct and those for 'direct plus indirect' use. The conclusion to be drawn from the above facts is that fuel oil is an input which is used directly by almost all industries in similar quantities and that its use is generally small. No other significant patterns emerge from the data on this resource.

## Lube Oil and Grease

This is an energy resource used in small quantities by all industries, with direct consumption being generally more important than indirect. The primary and primary manufacturing sectors have the highest average lube oil and grease content. In order to explain some of the pattern of utilization of this resource, those industries in the Primary and Primary Manufacturing sectors have been selected whose consumption is greater than the sector's average of 0.4¢. These industries together with their direct (D) and 'direct plus indirect' (DI) lube oil and grease contents are listed in Table 3.8.

Of the industries listed, only the Fish Products Industry and Leaf Tobacco Proc. have displayed large indirect inputs of lube oil and grease. Examination of the $[I - A]^{-1}$ 110 x 110 matrix will show clearly the source of these industries' indirect consumption of this resource. The Fish Products Ind. requires 52¢ of output from the Fishing and Hunting industry per dollar of final demand, and this latter industry has a direct Lube Oil and Grease

## Table 3.8

### Industries With Direct Plus Indirect Lube Oil and Grease Content > 0.4¢.

| Industry | DI | D |
|---|---|---|
| Primary | | |
| Agriculture | 0.5¢ | 0.4¢ |
| Fishing and Hunting | 1.1¢ | 1.0¢ |
| Coal Mines | 0.5¢ | 0.45¢ |
| AO. Non-Metal Mines | 1.0¢ | 0.9¢ |
| Primary Manufacturing | | |
| Fish Prod. Ind. | 0.7¢ | 0.04¢ |
| Leaf Tobacco Proc. | 0.5¢ | 0.004¢ |
| Cement and Lime Mfg. | 0.5¢ | 0.4¢ |
| Petroleum Prod. Ind. | 0.6¢ | 0.4¢ |

Source: Calculated from Dominion Bureau of Statistics, The Input-Output Structure of the Canadian Economy, 1961, Volume II, Table 13.

Table A.1 in the Appendix of this paper.

input of 1¢ per dollar. Similarly the Leaf Tobacco industry requires 92¢ of output from Agriculture which directly consumes 0.4¢ of Lube Oil and Grease per dollar of output.

Other Petroleum Products

These do not comprise a large proportion of the input of any of the sectors. However, the average consumption by the secondary manufacturing sector is noticeably above that of the others. Because of this, the industries in this sector will be examined in more detail. Those industries which are very large consumers of petroleum products are set out in Table 3.9. These industries display large direct consumption of petroleum products, probably mainly as feedstock. It is from these five industries that most of the indirect use of petroleum products is spread through

Table 3.9

Industries With Large Petroleum Products Content

| Industry | DI | D |
|---|---|---|
| Other Wood Ind. | 3.4 ¢ | 3.1 ¢ |
| Asphalt Roofing | 7.3 ¢ | 6.7 ¢ |
| Plastic Resin Mfg. | 4.2 ¢ | 2.5 ¢ |
| Paint and Varnish | 4.3 ¢ | 2.5 ¢ |
| Other Chemical Ind. | 6.2 ¢ | 5.2 ¢ |

Source: Calculated from Dominion Bureau of Statistics, The Input-Output Structure of the Canadian Economy, 1961, Volume II, Table 13.
Table A.2 in Appendix of this paper.

the rest of the economy.

Electric Power

This is, by far, the most important and generally used energy resource in the economy. There is very little difference between sectors with respect to average consumption of electric power. Almost all industries consume a significant amount of electric power directly and indirectly. There are, however, some industries which have electric power contents considerably above average. These industries are set out in Table 3.10.

Table 3.10

Industries With 'Direct Plus Indirect' Electric Power Content Greater than 4¢

| Industry | DI | D |
|---|---|---|
| Primary | | |
| Iron Mines | 6.6 ¢ | 4.9 ¢ |
| Coal Mines | 5.7 ¢ | 4.3 ¢ |
| Primary Manufacturing | | |
| Cement and Lime Mfg. | 6.3 ¢ | 4.2 ¢ |
| Pulp and Paper Mills | 5.6 ¢ | 3.7 ¢ |
| Copper Roll Cast. | 4.1 ¢ | 0.7 ¢ |
| Secondary Manufacturing | | |
| Other Non-Metal Min. | 7.9 ¢ | 4.9 ¢ |
| Other Chemical Ind. | 5.7 ¢ | 3.2 ¢ |
| Alum. Roll. Cast | 4.1 ¢ | 1.0 ¢ |
| Tertiary | | |
| Utilities | 23.1 ¢ | 19.1 ¢ |

Source: Calculated from Dominion Bureau of Statistics, The Input-Output Structure of the Canadian Economy, 1961, Volume II, Table 13.

Table A.2 in the Appendix of this paper.

With the exception of two industries, all the above have above average direct inputs of electric power. Although due to the general use of this energy resource, it is impossible to trace through the path of indirect use, it seems reasonable to assert that it is from the industries above that most of the indirect consumption feeds through the system.

## SUMMARY AND CONCLUSIONS

In this chapter, the 'direct and indirect' energy requirements of Canadian primary and manufacturing industries were examined. It was shown that direct plus indirect energy consumption was an important cost element in many of these industries. Furthermore, it was demonstrated that some industries, which would not have been considered as energy intensive on the basis of their direct energy use, turned out to be so when indirect use of energy was included. It was also shown that significant differences exist between industries, both with respect to overall 'direct and indirect' energy requirements and to the consumption of individual energy resources. Some of these differences were explained in terms of differential backward linkages to the directly energy intensive industries.

# Chapter IV

# THE PRICE OF ENERGY

## INTRODUCTION

In this chapter the effects of imposing price changes on the specific kinds of energy and the resultant price effects on final output will be analyzed. The study will be carried on within the Input-Output framework and will utilize the data calculated earlier in this paper. Since the price analysis is merely one way in which this data can be used, no attempt is made to conduct a detailed analysis of how a given energy policy would effect the output prices of specific industries. Rather, this chapter is methodological in that its intent is to provide a broad framework in which the information contained elsewhere in this paper can be applied to the specific problem of changing energy prices.

The uses of such price analysis are many. For example, it would be essential, in determining the effect of any proposed energy price change, to have a clear picture of how such changes would effect the competitive position of Canadian exports. The applications are not, however, restricted to the foreign trade sector. The technique could also be used to study the effects on regional output price differences of a policy designed to widen or narrow regional energy price differentials.

The plan of the chapter is as follows. Firstly, the assumptions used will be explicitly listed and some of their implications explored. Then it will be shown how the 'direct plus indirect' energy requirement coefficients displayed in Table A.2 can be used to predict the effect on output prices of any of the 110 industries, of a change in the price of any of the eight energy resources. Finally, the limitations of this type of approach will be set out, and more sophisticated models suggested.

## ASSUMPTIONS AND THEIR IMPLICATIONS

The assumptions used in the following analysis are very important in interpreting the results which are derived using the methods described. These are of two principal types, those which are implicit in the very nature of a static input-output model, and others which are peculiar to the problem at hand. The listing of assumptions which appears below is not complete, but focuses only on those which have immediate relevance to price analysis.

### A. General Assumptions of a static Input-Output Model:

i. No substitution among factors of production

ii. The inputs purchased by any sector are a function only of the level of output of that sector.

B. Particular assumption concerning the cost-price relation:

iii. All increases in costs are 'passed on' in the sense that when an industry is faced with an increase in input prices or factor prices, it is able to offset this increase in costs by increasing its output prices.

The assumption of no substitution among inputs ensures that when the relative prices of inputs are changed, no structural change occurs within the system. For example, raising the price of one energy resource while leaving the others unchanged will not result in that resource being replaced in production by one of the others. Although this seems like a very rigid restriction to impose on a model of this sort, it is probably reflective of real world behaviour in the short run. Producers, even if alternative input configurations are available, would not be likely to alter their processes unless they were certain that the new relative price structure was permanent. Also, switching from one fuel to another takes time as it involves changing capital plant and the technology implicit in this capital. However, it should be remembered that substitution among fuels is more easily achieved than with other general inputs.[1]

The second assumption, although it is analogous to the first, prevents an additional response to price. That is, when the price of a particular energy resource is raised, attempts would be made to improve fuel efficiency and eliminate waste. This would be particularly the case if the price increase were large. The end result of this action on the part of industry would be to reduce consumption of the resource whose price was increased, without altering output or causing substitution in favour of other energy sources.

The third assumption means, in effect, that the demand side of the picture is completely ignored. For example if the cost of delivering $1 worth of the output of any industry to final demand increases by 10¢ due to an energy price increase, the price of that given quantity of output will increase by 10¢. This, of course, ignores the reality that the increase in price may cause consumers to decrease their consumption of the product in question. This type of pricing behaviour would not be typical of a profit maximizing producer unless he were faced with the unlikely phenomenon of a perfectly inelastic demand for his product. In the absence of such conditions, the producer would be forced to absorb some of the increased costs himself, in the form of a reduced profit margin. Alternatively, where the market power of his non-energy suppliers is not strong, it might be possible for a producer to reduce the price of these inputs. By thus shifting his energy cost increases backward to his suppliers he could maintain his original profit margin without increasing the price of his products. In all cases except the one assumed here the increase in output prices would be less than proportional to the energy price increase.

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[1] For a discussion of changing input coefficients see: Anne P. Carter, Structural Change in the American Economy. (Cambridge, Mass.: Harvard University Press, 1970).

## CHANGING THE PRICE OF ENERGY

Having set out the assumptions, the effect of changing energy prices will now be examined. The task is relatively simple once the above restrictions are accepted. The procedure used involves simple operations on the coefficients set out in Table A.2 in the Appendix. These show the 'direct plus indirect' amount of each of the energy resources listed, required to deliver one dollar worth of the industry's output to final demand. They represent the energy cost of one dollar of final demand and changing the price of energy involves altering this cost. Given the assumptions above this cost change will be proportional to the energy price change and the cost change will be passed on entirely to the consumer in the form of a price change.

Taking the example of agriculture, its gasoline coefficient is .041572. This means that approximately 4.2¢ worth of gasoline is required directly and indirectly to deliver $1 worth of agricultural output to final demand. Now, if the price of gasoline is increased by, say, 50 percent, the amount of gasoline required will be 5.3¢. Under the cost-price assumption above, this will mean that the amount of agricultural produce previously represented by $1 of final demand will now fetch a price of $1.01. Similarly, a gasoline price increase of 100 percent would result in a comparable price being $1.02. Similar operations could be used to study the effect on any of the 110 industries of changing the price of one, or any number, of the energy resources.

Knowledge of the effects of changing energy prices are of great importance for projecting future economic profiles. Some of the wider implications of such price changes have been examined in great detail for some European economies in a report commissioned by the European Economic Community.[2] The assumptions adopted in this paper have, however, prevented the examination of many of the important regional and substitution problems, so well handled in the European report. However the data set out below could easily provide some of the basic raw material for future studies in these areas. For example, knowledge of which industries would be most affected by specific energy price changes, coupled with data on regional industrial structures, could show how different energy price patterns would differentially affect individual regions.

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[2] European Economic Community, L'influence economique du prix de l'energie (Etudes dans la serie economie et finances, No.4, Bruxelles, 1966).

In order, then, to give an indication of which industries would be most affected by changes in the prices of individual energy resources, a group of tables will now be presented. These list the top ten 'direct plus indirect' users of each of the energy resources. They thus represent the ten industries in each case which would be most affected by the given energy price change. In these tables (DI) means the amount of the specified energy resource required directly and indirectly to produce $1 worth of the output of the industry in question.

Table 4.1

Top 10 Users of Coal

| Industry | DI |
|---|---|
| Iron and Steel Mills | 6.4 ¢ |
| Cement and Lime Mfg. | 5.0 ¢ |
| Steel Pipe and Tube | 3.6 ¢ |
| Fabr. Struct. Metal | 2.5 ¢ |
| Metal Stamping | 2.2 ¢ |
| Wire and Prod. Mfg. | 2.0 ¢ |
| Clay, Stone and Refrac. | 1.9 ¢ |
| Border and Plate Works | 1.7 ¢ |
| Oth. Chemical Ind. | 1.7 ¢ |
| Vehicle Parts Mfg. | 1.5 ¢ |

## Table 4.2

## Top 10 Users of Crude Mineral Oil

| Industry | DI |
|---|---|
| Petroleum Products Ind. | 59.7 ¢ |
| Agriculture | 4.0 ¢ |
| Oth. Chemical Ind. | 3.9 ¢ |
| Sugar Refineries | 3.5 ¢ |
| Leaf Tobacco Proc. | 3.4 ¢ |
| Dairy Factories | 3.2 ¢ |
| Fishing & Hunting | 3.1 ¢ |
| Ao. Non-Metal Mines | 3.0 ¢ |
| Plastic Resin Mfg. | 3.0 ¢ |
| Flour Mills | 2.9 ¢ |

## Table 4.3

## Top 10 Users of Gasoline

| Industry | DI |
|---|---|
| Agriculture | 4.2 ¢ |
| Fishing & Hunting | 3.9 ¢ |
| Leaf Tobacco Proc. | 3.5 ¢ |
| Veg. Oil Mills | 3.4 ¢ |
| Dairy Factories | 3.2 ¢ |
| Meat Processors | 2.9 ¢ |
| Flour Mills | 2.9 ¢ |
| Fish Prod. Ind. | 2.3 ¢ |
| Feed Mills | 2.3 ¢ |
| Ao. Non-Metal Mines | 2.0 ¢ |

## Table 4.4

## Top 10 Users of Fuel Oil

| Industry | DI |
|---|---|
| Transp. and Storage | 2.8 ¢ |
| Clay, Stone and Refrac. | 2.3 ¢ |
| Glass & Prod. Mfg. | 2.2 ¢ |
| Iron Mines | 2.0 ¢ |
| Ao. Non-Metal Mines | 2.0 ¢ |
| Iron & Steel Mills | 1.9 ¢ |
| Operating Suppl. | 1.9 ¢ |
| Asbestos Mines | 1.7 ¢ |
| Pulp & Paper Mills | 1.7 ¢ |
| Concrete & Gypsum | 1.5 ¢ |

## Table 4.5

## Top 10 Users of Lube Oil & Grease

| Industry | DI |
|---|---|
| Fishing & Hunting | 1.1 ¢ |
| Ao. Non-Metal Mines | 1.0 ¢ |
| Fish Prod. Ind. | 0.7 ¢ |
| Petroleum Prod. Ind. | 0.6 ¢ |
| Agriculture | 0.5 ¢ |
| Coal Mines | 0.5 ¢ |
| Leaf Tobacco Proc. | 0.5 ¢ |
| Cement & Lime Mfg. | 0.5 ¢ |
| Iron Mines | 0.4 ¢ |
| Meat Processors | 0.4 ¢ |

## Table 4.6

### Top 10 Users of Other Petroleum Products

| Industry | DI |
|---|---|
| Asphalt Roofing | 7.3 ¢ |
| Oth. Chemical Inds. | 6.2 ¢ |
| Paint & Varnish | 4.3 ¢ |
| Plastic Resin Mfg. | 4.2 ¢ |
| Oth. Wood Ind. | 3.4 ¢ |
| Linol & Coated Fabric | 1.8 ¢ |
| Ao. Paper Convert. | 1.8 ¢ |
| Mixed Fertilizers | 1.6 ¢ |
| Oth. Rubber Ind. | 1.4 ¢ |
| Tire & Tube Mfg. | 1.4 ¢ |

## Table 4.7

### Top 10 Users of Electricity

| Industry | DI |
|---|---|
| Oth. Non-Metal Minerals | 7.9 ¢ |
| Oth. Metal Mines | 6.6 ¢ |
| Cement & Lime Mfg. | 6.3 ¢ |
| Coal Mines | 5.7 ¢ |
| Oth. Chemical Ind. | 5.7 ¢ |
| Pulp & Paper Mills | 5.6 ¢ |
| Smelting & Refining | 4.5 ¢ |
| Alum. Roll Cast | 4.1 ¢ |
| Copper Roll Cast | 4.1 ¢ |

## SUMMARY AND CONCLUSIONS

From the above, it can be seen how easily the effects of energy price changes can be calculated within the framework of the given set of assumptions. However, these latter comprise an oversimplification and the predictions derived must be viewed within this context. More sophisticated models are possible, but they require much more technical and economic information than was available for this paper.

Chenery and Clark[3] suggest a model which would take into account some of the substitution effects which were ignored above. Their procedure involves a sub-analysis of key areas, such as fuel consumption. Having calculated from an Input-Output model the energy required by industry, and converted it into some thermal units, they proceed to explore the different fuel substitution possibilities given alternative sets of assumed relative prices. The set of fuel consumption figures arrived at by this sub-analysis is then plugged back into the Input-Output model to check its effects and feasibility. Using a trial and error procedure, an energy consumption pattern is arrived at which is consistent with the assumed set of prices and with the Input-Output predictions. A procedure similar to this was used in an Input-Output study of the Italian Economy.[4] In this study a sub-analysis was used to test the feasibility of substituting domestic natural gas for imported coal in Italian industry over a five year period. The incorporation of this analysis into the overall input-output predictions yielded fairly reliable results.

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[3] Chenery and Clark, Interindustry Economics, Chapter 10.

[4] H.B. Chenery and P.G. Clark and V. Cao-Pinna, The Structure and Growth of the Italian Economy, (Rome: U.S. Mutual Security Agency, 1953).

However, even the more sophisticated models are far from perfect, as it is impossible to isolate all the different factors which would lead to a change in energy structure. ". . . changes in Input-Output structure subsume long and short-run substitution along with innovation and diffusion of new techniques. Operationally, some of these distinctions are very difficult to make, even in a framework that specifies variable coefficients."[5] Without being able to separate all the diverse factors involved in a changing energy consumption pattern, reliable prediction of the effects of one of these influences, such as price, is bound to be unreliable to some extent.

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[5] Carter, Structural Change in the American Economy, p. 217.

# Chapter V

# SOME RELATIONSHIPS BETWEEN ENERGY AND CANADIAN TRADE

## INTRODUCTION

In this chapter the 'direct plus indirect' energy content of Canada's foreign trade will be examined. The information gained by this analysis may be of use in evaluating the industrial ramifications of policies which would affect energy prices. Without consideration of indirect energy content, many of the broader implications of such policies would be impossible to calculate. Previous studies[1] have shown that Canadian exports are relatively capital and natural resource intensive. Furthermore, it has been shown that the export industries are directly energy intensive. However, in these studies, no attempt was made to take into account indirect energy content. Neglect of this element leads to an underestimation of the importance of energy resources as a cost element in the exporting and import-competing industries.

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[1] B. W. Wilkinson, Canada's International Trade: An Analysis of Recent Trends and Patterns. (Canadian Trade Committee, 1968).

Knowing the natural resource or capital content of commodity trade means that it is possible to make judgments on where a country's comparative advantage lies. Knowledge of 'direct plus indirect' energy intensities does not confer as much analytical power, but it does provide a basis for estimating the effect on our trade balance of changing that particular cost element through different energy policies. The net effect on trade flows of such price changes may be slight but it is with such marginal elements that economic analysis is often concerned.

The format of this chapter will be as follows. Firstly, four groups of industries will be classified with respect to trade, and then the average energy intensities of each of these groups will be calculated. From this data, it will be shown that, on average, Canadian exporting industries are more energy intensive than import competing ones. Then the industries within each of the above groups will be allocated to sectors--primary, primary manufacturing and secondary manufacturing. The relative importance of energy in each of these sectors will then be studied. Following this, the paper will focus upon the individual energy resources and their relative positions in the trade sector. It will be shown that a certain few resources contribute in particular to the overall energy intensity of Canadian exporting industries and hence affecting their prices would have the broadest consequences for trade. Finally, it will be shown how the 'direct plus indirect' energy requirements of a given foreign trade pattern can be estimated using the data generated in this paper.

## FOREIGN TRADE CATEGORIES DEFINED AND EXAMINED

Data on imports and exports for 197 commodities were found in Table 13 of the Input-Output table for Canada.[2] These commodities were allocated to the 110 industries under study in this paper and corresponding import, export and domestic output figures were calculated. The industries were then divided into two principal groups, those whose exports amounted to greater than 15 percent of total domestic output (called the exporting industries), and those whose imports formed more than 15 percent of total domestic output (called the import-competing industries). Some industries were both 'exporting' and 'import-competing.' Consequently, another category, the 'net exporting industries,' was identified. It consists of those industries which are classified as exporting but whose exports also exceed imports.

The use of these industrial categories as a proxy for imports and exports involves a fairly rigid assumption. Namely, "that production techniques are essentially the same everywhere and that, therefore, the relative factor intensities of imports and exports can be approximated from the relative factor intensities of domestically produced import-competing goods and export goods."[3] Having defined these trade categories, it now remains to calculate their average 'direct plus indirect' energy intensities. These will be compared with each other and with the average for the total of 110 industries. These averages are listed in Table 5.1.

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[2] Dominion Bureau of Statistics, The Input-Output Structure of the Canadian Economy, 1961. Vol. II, Table 13.

Table 5.1

Energy Inputs - Foreign Trade Averages

| All Industry | Exporting Inds. | Net Exporting Inds. | Import Competing Inds. |
|---|---|---|---|
| 7.9¢ | 8.9¢ | 8.5¢ | 7.2¢ |

Source: Calculated from data in Appendix, Table A.1.

From the above, it can be seen immediately that the exporting and net exporting industries are much more energy intensive on average than either the total of 110 industries or the import-competing ones. It is not valid, however, to infer from this that Canadian exports are more energy intensive than imports. This is so because the averages used in Table 5.1 are simple, and thus give equal weight to every industry regardless of its size. However, indications from previous studies[4] are that weighting by some measure of industry importance would, in fact, reinforce the trend observed above. The results then confirm the intuitive notion that Canada, due to its relative abundance of high quality energy resources, would be a net exporter 'directly plus indirectly' of these. The above facts are of theoretical importance, but more practical information can be gained by studying the same picture at a more disaggregated level.

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[3] Wilkinson, B. W., Canada's International Trade: An Analysis of Recent Trends and Patterns, p. 87, n. 6.

## SECTOR ANALYSIS

In this section the relative energy content of the different sectors within each of the three trade categories is examined. Such differentials as exist are important in that they provide some idea of what impact a shift in the sector composition of trade might have on energy consumption. The data relevant to the following analysis is set out in Table 5.2.

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[4] Ibid.

For the primary industries there is no difference among the trade categories in average energy intensity. With the primary manufacturing industries some differences begin to emerge. The exporting and net exporting industries here are the same, and they are substantially more energy intensive than the import-competing primary industries. It is from this sector that most of Canada's manufactured exports come[5] and hence the energy position here accounts for large net exports of embodied energy. For the secondary manufacturing industries, the difference in energy content between the exporting and importing industries is even

Table 5.2

Energy Inputs - Foreign Trade by Sector

| | Exporting Industries | Net Exporting Industries | Import-Competing Industries |
|---|---|---|---|
| Primary | 8.5¢<br>(n = 8) | 8.5¢<br>(n = 6) | 8.5¢<br>(n = 4) |
| Primary Mfg. | 8.4¢<br>(n = 9) | 8.4¢<br>(n = 9) | 7.8¢<br>(n = 4) |
| Secondary Mfg. | 9.8¢<br>(n = 7) | 8.8¢<br>(n = 3) | 7.0¢<br>(n = 38) |

n = number of industries in category

Source: Calculated from data in Appendix, Table A.1.

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[5] *Ibid*. p. 100.

more pronounced. The 9.8¢ worth of energy consumed, directly and indirectly, by the exporting industries here is considerably greater than the 7¢ worth consumed by the import competing industries or the 7.1¢ worth by the total of all secondary manufacturers. Thus, although in the overall picture of the economy, secondary manufacturing is on average the least energy intensive of the sectors under consideration, it is clear that a set of particularly heavy energy users emerge as the exporting industries from this sector. In a paper of this type it is only possible to conjecture that these particular industries emerge as the export performing ones, due to some comparative advantage they derive through Canada's relative abundance of high quality energy resources. It is now proposed to continue the study of trade at the level of individual energy resources.

## THE INDIVIDUAL ENERGY RESOURCES AND TRADE

Knowledge of the relative importance of each specific energy resource as a cost, in the commodities that enter into Canada's foreign trade, is essential if any action is contemplated which would change their relative price structure. Thus, in this section an attempt will be made to outline the energy structure of Canada's foreign trade. The amount of each of the energy resources, on average, required, directly and indirectly, by each sector for each of the trade categories and for the total 110 industries is set out in Table 5.3.

## Primary Industries

For the primary industries, the most important energy resource is electric power followed closely by crude mineral oil and gasoline. There is very little deviation by any of the trade categories from the sector average in any resource. The exception to this is the import-competing industries whose average consumption of gasoline is less, and that of electric power considerably greater than the average of all primary industries. Three of the four import-competing industries have below average gasoline consumption while one, coal mines, has a very large electric power consumption figure at 5.7¢ per dollar of final demand.

## Primary Manufacturing

For the primary manufacturing industries, the most important energy resource is electric power followed by crude mineral oil and gasoline. Differences among the groups listed occurs only for coal, electric power and crude mineral oil. For coal, the exporting and net exporting industries are below the average of all primary manufacturing industries, while the import competing industries are above this

## Table 5.3

### Average Energy Resource Inputs - By Sector and Trade Category

| | Coal | CrudeMineral Oil | Nat. Gas | Gasoline | Fuel Oil | Lube Oil and Grease | Oth. Petroleum Products | Electric Power |
|---|---|---|---|---|---|---|---|---|
| Primary | | | | | | | | |
| Exporting | 0.3 | 2.0 | N.A. | 1.5 | 1.2 | 0.5 | 0.2 | 2.8 |
| Net. Exporting | 0.3 | 2.0 | N.A. | 1.5 | 1.1 | 0.5 | 0.2 | 2.9 |
| Import Competing | 0.4 | 1.6 | N.A. | 0.8 | 1.3 | 0.5 | 0.2 | 3.6 |
| All Primary | 0.3 | 1.8 | N.A. | 1.3 | 1.1 | 0.4 | 0.2 | 2.9 |
| Primary Mfg. | | | | | | | | |
| Exporting | 0.6 | 1.9 | N.A. | 1.5 | 1.2 | 0.3 | 0.4 | 2.5 |
| Net Exporting | 0.6 | 1.9 | N.A. | 1.5 | 1.2 | 0.3 | 0.4 | 2.5 |
| Import Competing | 1.1 | 1.7 | N.A. | 1.2 | 1.3 | 0.2 | 0.4 | 2.2 |
| All Primary Mfg. | 0.9 | 2.2 | N.A. | 1.5 | 1.2 | 0.3 | 0.3 | 2.9 |
| Secondary Mfg. | | | | | | | | |
| Exporting | 0.9 | 1.7 | N.A. | 0.3 | 0.9 | 0.2 | 1.7 | 4.1 |
| Net Exporting | 0.8 | 1.1 | N.A. | 0.2 | 1.0 | 0.2 | 0.4 | 5.4 |
| Import Competing | 0.8 | 1.3 | N.A. | 0.4 | 0.9 | 0.2 | 0.9 | 2.5 |
| All Secondary Mfg. | 0.9 | 1.3 | N.A. | 0.5 | 0.9 | 0.2 | 0.8 | 2.3 |
| Total 110 Ave. | 0.7 | 2.0 | N.A. | 0.7 | 1.0 | 0.2 | 0.6 | 2.5 |

Source: Calculated from data in Appendix, Table A.2.

average. One of the four import competing industries, Clay, Stone and Refrac, is responsible for their high average. This industry consumes directly and indirectly 1.9¢ worth of coal[6] per dollar of final demand. For crude mineral oil and electric power, all the trading categories are considerably below the average of all the primary manufacturing industries.

## Secondary Manufacturing

For these industries, the most significant energy resources are crude mineral oil and electric power. For two resources, 'electric power' and 'other petroleum products' the exporting industries are considerably above the average of all secondary manufacturing industries. The above average consumption of other petroleum products by the exporters is explained by the heavy consumption of two industries. These are Plastic Resin Mfg. and Oth. Chemical Ind., with 4.2¢ and 6.2¢ worth, respectively, required per unit of final demand. The large usage of electric power by the secondary manufacturing exporting industries is explained by four heavy users. These are Oth. Non-Metal Min. (7.9¢), Oth. Chemical Ind. (5.7¢), Aluminum Roll Cast (4.1¢), and Copper Roll Cast (4.1¢).

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[6] It should be remembered that much of Canada's coal needs in 1961 were supplied by imports from the U.S.A.

## POLICY APPLICATIONS

### The Price of Energy and Foreign Trade

Having isolated the exporting, export performing and import-competing industries, and knowing their 'direct plus indirect' requirements of the various energy resources, it is possible to predict some of the impact on trade of changed energy prices. Once it has been determined to what extent a given policy would influence energy prices, the change in price of any of the industries caused by this change could be calculated using the methods described earlier. This price change could then be applied to an export price elasticity for the industry in question to determine the effect on export demand for this industry. There is, however, one major stumbling-block to using this approach. That is, export price elasticities of demand for Canadian products have not been estimated for a set of industries comparable to the 110 used in this paper. Those elasticities which have been calculated[7] vary so much between themselves as to make their application to a problem dubious.

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[7] L. H. Officer and J. R. Hurtubise, "Price Effects of the Kennedy Round on Canadian Trade," Review of Economics and Statistics, (August, 1969).

D. D. Demotasi, "The Elasticity of Demand for Canadian Exports to the U.S.," Canadian Journal of Economics, Vol. II, (August, 1969), 416-426.

However, at a less rigorous level, some interesting conclusions can be drawn from the data shown above. For example, it is possible to conclude, on the basis of this chapter, that increasing the price of electric power would have more effect on our export performance in the secondary manufacturing sector than would raising the price of any other energy resource. However, raising the price of any energy resource, as can be seen from the above, would have a differential impact on the various sectors. Thus, drawing conclusions with regard to the overall trade situation without explicitly taking into account the relative size of these sectors, and the different factors which affect their demand, would be a very dangerous procedure.

## Projecting the Energy Requirements for Trade

Through a direct application of the data set out in the Appendix, Table A.2, it would be possible to calculate the 'direct plus indirect' domestic energy resource requirements of a given pattern of Canadian foreign trade.[8] The procedure would involve

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[8] Similar methods were used to estimate the resource requirements of U. S. foreign trade. See:

University of Maryland, Bureau of Business and multiplying the energy requirements matrix separately by a vector of exports and a vector of competing imports, for those industries whose goods are traded. The result of this operation would be two (8 x 1) vectors giving, respectively, the 'direct plus indirect' energy requirements of exports and import competing production for each of the eight energy resources. By subtracting the latter from the former, a vector would emerge giving the domestic production requirements of each of the eight energy resources. Using this technique, various projections for exports and imports could be used and their implications for domestic energy production easily calculated.

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Economic Research, Some Relationships Between U. S. Consumption and Natural Resources 1899, 1947, 1954, (College Park, 1958); see also Jaroslav Vanek, The Natural Resource Content of United States Foreign Trade, 1870-1955, (Cambridge, Mass,: The M.I.T. Press, 1963), Chapter 7, Appendix.

Chapter VI

# SUMMARY AND CONCLUSIONS

The purpose of this thesis was to provide an accurate measure of the importance of energy inputs as a proportion of the total inputs going into Canadian primary and manufacturing industries. Using the technique of Input-Output analysis, an energy requirements matrix was constructed. On the basis of this, the direct and indirect energy intensities of these industries were analyzed.

In Chapter III, one hundred and ten industries were examined. It was found that 'direct plus indirect' energy consumption was an important cost element in many of these industries. Also, some industries, which were not large direct users of energy, emerged as energy intensive when indirect consumption was included in the measure of energy use. This proved that indirect use of energy is important in total use, and that ignoring it leads to an underestimation of the number of energy intensive industries in the economy.

Significant variations were shown to exist between industries with respect to their total requirements of energy. Some of these differences were caused by variations in the direct inputs of energy used, and some by differences in the indirect energy requirements. Some of the variations in indirect use were explained by the differential backward linkages of the industries concerned to the directly energy intensive industries.

In Chapter IV it was shown how the energy requirement coefficients calculated in this paper can be used to predict the changes in output prices that would be brought about by altering the price of any of the energy inputs. The assumptions implicit in this type of analysis were described and alternative models of price determination were suggested.

In Chapter V the energy content of Canadian foreign trade was examined. It was shown that the exporting industries were, on average, more energy intensive than the import-competing ones. Furthermore, the relative importance of the different energy sources as inputs into the trading industries was examined. It was then explained how such information could be used to predict the effect on Canadian foreign trade of changing the price of any of these resources. Finally in this chapter, it was shown how the domestic production requirements for each of the eight energy resources could be calculated for any given pattern of international trade.

By far the most important limitation for this paper was that Input-Output data was not available for any year after 1961. As a result, the changes in the energy consumption pattern which have taken place since that date could not be quantified. However, Statistics Canada is at present compiling Input-Output tables that would cover the years from 1961 to 1967. When this data is released, the techniques outlined in Chapter II could easily be applied to it. This would then provide a more accurate picture of the present energy consumption pattern in the Canadian economy. If energy requirements data are calculated for 1967 they could then be compared with the data in this paper, to provide a picture of the way in which 'direct plus indirect' energy requirement coefficients change over time. Such an analysis would be very valuable in making long run energy consumption projections more accurate. However, given that more recent data are not available, the data set out in this paper provide the best approximation of the pattern of 'direct plus indirect' energy use in the Canadian economy possible at this time.

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# APPENDIX

# APPENDIX

The tables in this section contain the bulk of the data used in this thesis. The way in which these tables were derived is explained in Chapter 2.

The columns in each of these tables are numbered from 1 to 110. These numbers refer to the industries contained in the Dominion Bureau of Statistics listing of 110 Input-Output industries.[1] These industries together with their corresponding numbers are listed below.

| 110 Industry Aggregation Number | Input-Output 110 Industry Aggregation Title |
|---|---|
| 1 | Agriculture |
| 2 | Forestry |
| 3 | Fishing, Hunting |
| 4 | Iron Mines |
| 5 | Base Metal Mines |
| 6 | Uranium Mines |
| 7 | Other Metal Mines |
| 8 | Coal Mines |
| 9 | Petroleum, Nat. Gas |
| 10 | Asbestos Mines |
| 11 | Ao Non-Metal Mines |
| 12 | Meat Processors |
| 13 | Poultry Processors |
| 14 | Dairy Factories |
| 15 | Process Cheese |
| 16 | Fish Prod. Ind. |

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[1] Dominion Bureau of Statistics, The Input-Output Structure of the Canadian Economy, 1961. Vol. I, pp. 182-186.

| 110 Industry Aggregation Number | Input-Output 110 Industry Aggregation Title |
|---|---|
| 17 | Fruit and Veg. Canners |
| 18 | Feed Mills |
| 19 | Flour Mills |
| 20 | Breakfast Cereal |
| 21 | Biscuit Mfg. |
| 22 | Bakeries |
| 23 | Confectionery Mfg. |
| 24 | Sugar Refineries |
| 25 | Veg. Oil Mills |
| 26 | Misc. Food Ind. |
| 27 | Soft Drink Mfg. |
| 28 | Distilleries |
| 29 | Brewing and Winery |
| 30 | Leaf Tobacco Proc. |
| 31 | Tobacco Prod. Mfg. |
| 32 | Rubber Footwear |
| 33 | Tire and Tube Mfg. |
| 34 | Oth. Rubber Ind. |
| 35 | Leather Tanneries |
| 36 | Shoe Factories |
| 37 | Glove and Luggage |
| 38 | Cotton Yarn and Cloth |
| 39 | Wool Yarn and Cloth |
| 40 | Syn. Textile Mills |
| 41 | Carpet, Mat, Rug |
| 42 | Linol. and coated Fab. |
| 43 | Textile Bag and Canvas |
| 44 | Oth. Textile Ind. |
| 45 | Hosiery Mills |
| 46 | Other Knitting |
| 47 | Clothing Ind. |
| 48 | Saw Mills |
| 49 | Veneer and Plywood |
| 50 | Sash and Door and Planing |
| 51 | Other Wood Ind. |
| 52 | House Furniture |
| 53 | Oth. Furniture Ind. |
| 54 | Pulp and Paper Mills |
| 55 | Asphalt Roofing |
| 56 | Paper Box and Bag Mfg. |
| 57 | Ao Paper Convert. |
| 58 | Print - Publishing |
| 59 | Iron and Steel Mills |
| 60 | Steel Pipe and Tube |

| 110 Industry Aggregation Number | Input-Output 110 Industry Aggregation Title |
|---|---|
| 61 | Iron Founderies |
| 62 | Smelting and Refining |
| 63 | Alum. Roll. Cast. |
| 64 | Copper Roll. Cast. |
| 65 | Metal Roll. Cast. |
| 66 | Boiler and Plate Works |
| 67 | Fabr. Struct. Metal |
| 68 | Orn. and Arch. Metal |
| 69 | Metal Stamping |
| 70 | Wire and Prod. Mfg. |
| 71 | Hardware and Cutlery |
| 72 | Other Metal Ind. |
| 73 | Ao. Machinery Mfg. |
| 74 | Refrig. and Store Machinery |
| 75 | Aircraft and Parts |
| 76 | Motor Vehicle Mfg. |
| 77 | Vehicle Parts Mfg. |
| 78 | Oth. Transport Eq. Ind. |
| 79 | Electrical Appliance |
| 80 | Com. Eq. and Wire Mfg. |
| 81 | Electrical Indust. Eq. |
| 82 | Oth. Electrical Prod. Ind. |
| 83 | Cement and Lime Mfg. |
| 84 | Concrete and Gypsum |
| 85 | Clay, Stone and Refrac. |
| 86 | Glass and Prod. Mfg. |
| 87 | Oth. Non-Metal Minerals |
| 88 | Petroleum Products Ind. |
| 89 | Explosives and Ammunition |
| 90 | Mixed Fertilizer |
| 91 | Plastic Resin Mfg. |
| 92 | Pharmaceutical |
| 93 | Paint and Varnish |
| 94 | Soaps and Cleaners |
| 95 | Toilet Prep. Mfg. |
| 96 | Oth. Chemicals Ind. |
| 97 | Misc. Mfg. Ind. |
| 98 | Construction |
| 99 | Wh. and Retail Trade |
| 100 | Transport and Storage |

| 110 Industry Aggregation Number | Input-Output 110 Industry Aggregation Title |
|---|---|
| 101 | Communications |
| 102 | Utilities |
| 103 | Fin. Insur. Rl.Est. |
| 104 | Health and Education |
| 105 | Business Services |
| 106 | Hotel, Restaurant |
| 107 | Oth. Services |
| 108 | Office Supplies |
| 109 | Advt. and Travel |
| 110 | Operating Suppl. |

## Table A:1

### The 'Direct and Indirect' Energy Requirements of 110 Industries per $ of Final Demand

```
         1         2         3         4         5         6         7         8         9        10
1  0.123665  0.077487  0.092961  0.080256  0.337345  0.048404  0.039904  0.087085  0.046922  0.075098
        11        12        13        14        15        16        17        18        19        20
1  0.124671  0.357373  0.100409  0.130565  0.350032  0.084120  0.071039  0.092394  0.101642  0.061874
        21        22        23        24        25        26        27        28        29        30
1  0.058555  0.073147  0.052664  0.036022  0.115129  0.057744  0.048064  0.042046  0.053866  0.110036
        31        32        33        34        35        36        37        38        39        40
1  0.069145  0.050321  0.067917  0.070688  0.327493  0.047304  0.055346  0.046534  0.061091  0.076501
        41        42        43        44        45        46        47        48        49        50
1  0.062957  0.049214  0.045440  0.055819  0.115674  0.051531  0.040520  0.060954  0.066139  0.053684
        51        52        53        54        55        56        57        58        59        60
1  0.040671  0.047344  0.048746  0.115362  0.165675  0.079080  0.088951  0.044261  0.147248  0.104485
        61        62        63        64        65        66        67        68        69        70
1  0.071075  0.031191  0.077477  0.075829  0.087812  0.064204  0.075243  0.059095  0.073607  0.072667
        71        72        73        74        75        76        77        78        79        80
1  0.050712  0.061230  0.050541  0.024800  0.040291  0.051039  0.063075  0.057382  0.057011  0.040714
        81        82        83        84        85        86        87        88        89        90
1  0.046091  0.044920  0.162056  0.093868  0.112924  0.092792  0.120951  0.055066  0.079652  0.051731
        91        92        93        94        95        96        97        98        99       100
1  0.137696  0.045524  0.117407  0.073312  0.056962  0.153539  0.054075  0.064355  0.059446  0.090105
       101       102       103       104       105       106       107       108       109       110
1  0.017940  0.254940  0.015652  0.025532  0.014223  0.047120  0.046514  0.050844  0.057467  0.079575
```

In Table A.2 the row numbers refer to the energy resources. These resources and their corresponding numbers are listed below.

| Number | Resource Name |
|---|---|
| 1 | Coal |
| 2 | Crude Mineral Oil |
| 3 | Natural Gas |
| 4 | Gasoline |
| 5 | Fuel Oil |
| 6 | Lube. Oil and Grease |
| 7 | Other Petroleum Products |
| 8 | Electric Power |

# Table A:2

## The 'Direct and Indirect' Requirements for the Eight Energy Resources by the 110 Industries per $ of Final Demand

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.007937 | 0.001555 | 0.001406 | 0.001642 | 0.001951 | 0.006305 | 0.003151 | 0.005369 | 0.001108 | 0.003073 |
| 2 | 0.039831 | 0.024655 | 0.031299 | 0.017308 | 0.004669 | 0.007968 | 0.007070 | 0.008611 | 0.009095 | 0.013663 |
| 3 | 0.000291 | 0.000178 | 0.000238 | 0.000186 | 0.000150 | 0.000188 | 0.000349 | 0.000129 | 0.000408 | 0.000322 |
| 4 | 0.041572 | 0.018767 | 0.035249 | 0.003040 | 0.001566 | 0.001791 | 0.002094 | 0.003238 | 0.005252 | 0.002373 |
| 5 | 0.013500 | 0.016408 | 0.002954 | 0.032044 | 0.004668 | 0.006998 | 0.006137 | 0.006463 | 0.006124 | 0.0166[illegible] |
| 6 | 0.005278 | 0.003180 | 0.010664 | 0.032018 | 0.000909 | 0.002821 | 0.002355 | 0.004560 | 0.002337 | 0.003420 |
| 7 | [illegible] | 0.016169 | 0.001420 | 0.001944 | 0.001048 | 0.002744 | 0.001959 | 0.001156 | 0.001215 | 0.001436 |
| 8 | 0.017149 | 0.006536 | 0.005477 | 0.030674 | 0.022396 | 0.019749 | 0.065788 | 0.056858 | 0.021386 | 0.034210 |

| | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.007970 | 0.003312 | 0.002735 | 0.004067 | 0.003048 | 0.003273 | 0.006693 | 0.003319 | 0.003010 | 0.005354 |
| 2 | 0.030033 | 0.022476 | 0.025305 | 0.031952 | 0.015353 | 0.024351 | 0.016600 | 0.025004 | 0.029494 | 0.014821 |
| 3 | 0.000027 | 0.000462 | 0.000473 | 0.001453 | 0.000536 | 0.000251 | 0.000565 | 0.000464 | 0.000323 | 0.000949 |
| 4 | 0.014436 | 0.026572 | 0.026734 | 0.031506 | 0.011253 | 0.022478 | 0.012031 | 0.023018 | 0.028813 | 0.010522 |
| 5 | 0.020103 | 0.011437 | 0.011554 | 0.013308 | 0.008376 | 0.010485 | 0.009715 | 0.011358 | 0.011920 | 0.006825 |
| 6 | 0.010078 | 0.003857 | 0.004082 | 0.004036 | 0.001895 | 0.006589 | 0.002240 | 0.003243 | 0.003862 | 0.002267 |
| 7 | 0.002383 | 0.002030 | 0.003457 | 0.002244 | 0.003428 | 0.002112 | 0.002994 | 0.002933 | 0.002958 | 0.002472 |
| 8 | 0.033230 | 0.017924 | 0.019701 | 0.019904 | 0.016143 | 0.014126 | 0.018169 | 0.022955 | 0.021262 | 0.018665 |

| | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.003571 | 0.002873 | 0.004301 | 0.004217 | 0.004730 | 0.003838 | 0.002999 | 0.005154 | 0.003421 | 0.003243 |
| 2 | 0.014022 | 0.014402 | 0.010591 | 0.039376 | 0.034569 | 0.014627 | 0.012729 | 0.010229 | 0.012707 | 0.034280 |
| 3 | 0.001936 | 0.006857 | 0.000467 | 0.001068 | 0.000334 | 0.000734 | 0.000389 | 0.000542 | 0.000428 | 0.000271 |
| 4 | 0.010041 | 0.017235 | 0.006038 | 0.005143 | 0.033988 | 0.009947 | 0.004740 | 0.005520 | 0.006554 | 0.035016 |
| 5 | 0.007401 | 0.039136 | 0.007272 | 0.008397 | 0.014131 | 0.008374 | 0.007059 | 0.007468 | 0.008186 | 0.012680 |
| 6 | 0.002021 | 0.002055 | 0.001278 | 0.000586 | 0.004440 | 0.001776 | 0.001672 | 0.001161 | 0.002061 | 0.004535 |
| 7 | 0.003649 | 0.003236 | 0.003167 | 0.001227 | 0.003273 | 0.002923 | 0.002427 | 0.001694 | 0.002403 | 0.003272 |
| 8 | 0.016813 | 0.017951 | 0.017180 | 0.007578 | 0.020648 | 0.015536 | 0.012032 | 0.010081 | 0.017207 | 0.016736 |

| | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.002863 | 0.005675 | 0.005540 | 0.006615 | 0.010319 | 0.004669 | 0.005273 | 0.007112 | 0.007569 | 0.004872 |
| 2 | 0.014867 | 0.009034 | 0.010557 | 0.013476 | 0.018900 | 0.009754 | 0.011650 | 0.000755 | 0.011043 | 0.015878 |
| 3 | 0.000286 | 0.000016 | 0.000849 | 0.000609 | 0.000471 | 0.000316 | 0.000436 | 0.000289 | 0.000360 | 0.000858 |
| 4 | 0.019304 | 0.007552 | 0.001782 | 0.002363 | 0.012970 | 0.004939 | 0.005291 | 0.001555 | 0.004534 | 0.002478 |
| 5 | 0.004816 | 0.005640 | 0.004190 | 0.007148 | 0.010511 | 0.004067 | 0.007187 | 0.005557 | 0.008434 | 0.013948 |
| 6 | 0.002649 | 0.001051 | 0.001228 | 0.001346 | 0.002350 | 0.001174 | 0.001677 | 0.001072 | 0.001510 | 0.001364 |
| 7 | 0.003124 | 0.006753 | 0.012825 | 0.013838 | 0.027670 | 0.004379 | 0.005350 | 0.003975 | 0.004588 | 0.010048 |
| 8 | 0.015747 | 0.014469 | 0.026337 | 0.025302 | 0.024097 | 0.010566 | 0.018445 | 0.023633 | 0.022632 | 0.027261 |

| | 41 | 42 | 43 | 44 | 45 | 46 | 47 | 48 | 49 | 50 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.000948 | 0.007875 | 0.004544 | 0.005105 | 0.004425 | 0.005623 | 0.003315 | 0.001356 | 0.001987 | 0.002069 |
| 2 | 0.011002 | 0.018713 | 0.008690 | 0.010529 | 0.009232 | 0.009469 | 0.007952 | 0.014391 | 0.014415 | 0.011467 |
| 3 | 0.000452 | 0.000458 | 0.000344 | 0.000482 | 0.000380 | 0.000344 | 0.000260 | 0.000153 | 0.000396 | 0.000276 |
| 4 | 0.002981 | 0.004285 | 0.003001 | 0.003150 | 0.002183 | 0.002632 | 0.003537 | 0.013413 | 0.009026 | 0.007546 |
| 5 | 0.003367 | 0.003271 | 0.006911 | 0.008048 | 0.007295 | 0.007808 | 0.005759 | 0.013616 | 0.009572 | 0.008348 |
| 6 | 0.001331 | 0.001551 | 0.001135 | 0.001202 | 0.000494 | 0.001168 | 0.001071 | 0.002402 | 0.001997 | 0.001540 |
| 7 | 0.006576 | 0.019455 | 0.004248 | 0.000011 | 0.004765 | 0.004969 | 0.003267 | 0.002513 | 0.004717 | 0.002580 |
| 8 | 0.022547 | 0.027480 | 0.020166 | 0.021212 | 0.018866 | 0.019514 | 0.015356 | 0.018135 | 0.024029 | 0.019839 |

## Table A.2 (continued)

| | 51 | 52 | 53 | 54 | 55 | 56 | 57 | 58 | 59 | 60 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.003849 | 0.004681 | 0.008832 | 0.014027 | 0.006107 | 0.007834 | 0.006650 | 0.003751 | 0.064100 | 0.036498 |
| 2 | 0.024799 | 0.008724 | 0.008550 | 0.016169 | 0.044272 | 0.013303 | 0.018121 | 0.007634 | 0.015355 | 0.012128 |
| 3 | 0.000426 | 0.000386 | 0.000455 | 0.001228 | 0.001292 | 0.000750 | 0.000666 | 0.000428 | 0.000943 | 0.001038 |
| 4 | 0.006009 | 0.003687 | 0.003471 | 0.006215 | 0.003527 | 0.004022 | 0.003830 | 0.003083 | 0.002765 | 0.002320 |
| 5 | 0.007651 | 0.006419 | 0.006878 | 0.016593 | 0.012081 | 0.010418 | 0.010589 | 0.006004 | 0.019094 | 0.013730 |
| 6 | 0.001466 | 0.001051 | 0.001087 | 0.001977 | 0.001913 | 0.001534 | 0.001483 | 0.001307 | 0.002970 | 0.002614 |
| 7 | 0.034441 | 0.004062 | 0.003317 | 0.003516 | 0.073068 | 0.008209 | 0.018027 | 0.002393 | 0.001866 | 0.002602 |
| 8 | 0.020031 | 0.018935 | 0.018375 | 0.055638 | 0.026365 | 0.033010 | 0.029484 | 0.019660 | 0.040159 | 0.033559 |

| | 61 | 62 | 63 | 64 | 65 | 66 | 67 | 68 | 69 | 70 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.012702 | 0.012689 | 0.008955 | 0.009730 | 0.007086 | 0.016983 | 0.024872 | 0.011301 | 0.021714 | 0.020760 |
| 2 | 0.010281 | 0.008523 | 0.009948 | 0.008803 | 0.010903 | 0.009398 | 0.009573 | 0.009709 | 0.009428 | 0.008741 |
| 3 | 0.000642 | 0.000702 | 0.000818 | 0.000898 | 0.000902 | 0.000535 | 0.000576 | 0.000659 | 0.000896 | 0.001136 |
| 4 | 0.002818 | 0.001773 | 0.001942 | 0.002037 | 0.002910 | 0.003319 | 0.002941 | 0.003557 | 0.002464 | 0.002193 |
| 5 | 0.009825 | 0.009787 | 0.011190 | 0.009378 | 0.011613 | 0.009314 | 0.010346 | 0.008676 | 0.009763 | 0.009017 |
| 6 | 0.002827 | 0.001251 | 0.001497 | 0.001757 | 0.001794 | 0.001474 | 0.001745 | 0.001600 | 0.001472 | 0.001850 |
| 7 | 0.002142 | 0.001813 | 0.002561 | 0.002022 | 0.002856 | 0.001858 | 0.001725 | 0.001956 | 0.002814 | 0.002152 |
| 8 | 0.029842 | 0.044956 | 0.040567 | 0.041164 | 0.029548 | 0.021323 | 0.023565 | 0.021198 | 0.025056 | 0.026818 |

| | 71 | 72 | 73 | 74 | 75 | 76 | 77 | 78 | 79 | 80 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.008620 | 0.012553 | 0.010638 | 0.002738 | 0.004101 | 0.009679 | 0.015026 | 0.010710 | 0.010724 | 0.004307 |
| 2 | 0.008271 | 0.008976 | 0.007559 | 0.005098 | 0.007925 | 0.008121 | 0.008603 | 0.008063 | 0.008691 | 0.006383 |
| 3 | 0.000628 | 0.000799 | 0.000568 | 0.000234 | 0.000337 | 0.000559 | 0.000772 | 0.000415 | 0.000628 | 0.000447 |
| 4 | 0.002632 | 0.002757 | 0.002383 | 0.002765 | 0.003565 | 0.002601 | 0.002467 | 0.002125 | 0.002392 | 0.001705 |
| 5 | 0.007801 | 0.008987 | 0.007173 | 0.003548 | 0.005850 | 0.006293 | 0.007886 | 0.008976 | 0.007864 | 0.005465 |
| 6 | 0.001102 | 0.001329 | 0.001358 | 0.000575 | 0.001954 | 0.002055 | 0.002594 | 0.001047 | 0.001548 | 0.000923 |
| 7 | 0.002058 | 0.002032 | 0.001830 | 0.001311 | 0.002266 | 0.002937 | 0.002096 | 0.001820 | 0.002619 | 0.002973 |
| 8 | 0.019599 | 0.023796 | 0.019432 | 0.008530 | 0.014283 | 0.018763 | 0.023630 | 0.024226 | 0.022543 | 0.018506 |

| | 81 | 82 | 83 | 84 | 85 | 86 | 87 | 88 | 89 | 90 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.008095 | 0.005261 | 0.050829 | 0.013661 | 0.019231 | 0.003500 | 0.006165 | 0.003051 | 0.007743 | 0.006868 |
| 2 | 0.007071 | 0.007958 | 0.015439 | 0.017899 | 0.020400 | 0.018154 | 0.012787 | 0.597537 | 0.015210 | 0.016544 |
| 3 | 0.000437 | 0.000473 | 0.006157 | 0.001627 | 0.004184 | 0.002106 | 0.000936 | 0.000737 | 0.000769 | 0.001267 |
| 4 | 0.001896 | 0.002285 | 0.005394 | 0.009505 | 0.006175 | 0.002929 | 0.002982 | 0.005153 | 0.002412 | 0.005257 |
| 5 | 0.005993 | 0.006123 | 0.014316 | 0.015137 | 0.023220 | 0.021900 | 0.010800 | 0.007841 | 0.012736 | 0.005471 |
| 6 | 0.002288 | 0.000986 | 0.005027 | 0.003544 | 0.002786 | 0.001955 | 0.001755 | 0.006135 | 0.001550 | 0.002841 |
| 7 | 0.001860 | 0.003584 | 0.001881 | 0.002896 | 0.002770 | 0.005133 | 0.006393 | 0.009951 | 0.010982 | 0.016472 |
| 8 | 0.018450 | 0.017949 | 0.062969 | 0.029599 | 0.034059 | 0.027116 | 0.079135 | 0.025062 | 0.028250 | 0.031011 |

| | 91 | 92 | 93 | 94 | 95 | 96 | 97 | 98 | 99 | 100 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.008259 | 0.002748 | 0.006609 | 0.007777 | 0.003582 | 0.017026 | 0.005417 | 0.006250 | 0.001001 | 0.002412 |
| 2 | 0.030454 | 0.011754 | 0.029168 | 0.016790 | 0.014925 | 0.038542 | 0.010238 | 0.015638 | 0.012833 | 0.028851 |
| 3 | 0.001702 | 0.000423 | 0.000882 | 0.000664 | 0.000520 | 0.002357 | 0.000513 | 0.000450 | 0.000404 | 0.000381 |
| 4 | 0.003373 | 0.003565 | 0.004029 | 0.006510 | 0.003401 | 0.003036 | 0.002903 | 0.008146 | 0.010364 | 0.016225 |
| 5 | 0.010412 | 0.006887 | 0.007864 | 0.007858 | 0.007577 | 0.009307 | 0.006463 | 0.009862 | 0.013880 | 0.028255 |
| 6 | 0.002186 | 0.001148 | 0.001724 | 0.001709 | 0.001148 | 0.003263 | 0.001198 | 0.001904 | 0.001938 | 0.002652 |
| 7 | 0.042338 | 0.005524 | 0.042648 | 0.010483 | 0.010414 | 0.062624 | 0.007240 | 0.007988 | 0.001220 | 0.002264 |
| 8 | 0.038962 | 0.013474 | 0.024485 | 0.021520 | 0.015293 | 0.057383 | 0.020103 | 0.014122 | 0.017806 | 0.009066 |

Table A:2 (continued)

|  | 101 | 102 | 101 | 104 | 105 | 106 | 107 | 108 | 109 | 110 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.000628 | 0.007257 | 0.000772 | 0.000840 | 0.000459 | 0.001553 | 0.001401 | 0.004127 | 0.002387 | 0.004337 |
| 2 | 0.004424 | 0.004492 | 0.003425 | 0.006551 | 0.003750 | 0.012189 | 0.010879 | 0.009391 | 0.021962 | 0.021213 |
| 3 | 0.000046 | 0.000432 | 0.000246 | 0.020189 | 0.030685 | 0.000404 | 0.000195 | 0.000462 | 0.000331 | 0.000473 |
| 4 | 0.002350 | 0.002207 | 0.001306 | 0.003627 | 0.002151 | 0.007499 | 0.004411 | 0.003590 | 0.005980 | 0.011198 |
| 5 | 0.003815 | 0.096459 | 0.003036 | 0.005042 | 0.002026 | 0.010130 | 0.003045 | 0.006962 | 0.009493 | 0.018856 |
| 6 | 0.000499 | 0.000425 | 0.000282 | 0.000962 | 0.003363 | 0.001191 | 0.000848 | 0.001302 | 0.001380 | 0.002161 |
| 7 | 0.003842 | 0.030342 | 0.001038 | 0.001341 | 0.000624 | 0.001690 | 0.004403 | 0.005027 | 0.002267 | 0.006447 |
| 8 | 0.005296 | 0.236735 | 0.005577 | 0.006981 | 0.004815 | 0.012563 | 0.015631 | 0.015584 | 0.013667 | 0.014870 |